The STEREO Mission: getting the message across

In 2007, NASA launched two satellites, STEREO-A and STEREO-B that were to slowly drift away from Earth in opposite directions, taking 'stereo' images of the sun as they went. Getting the information and images back to Earth posed a challenge because the farther away they drifted, the weaker the signal got. The table below gives the distance of STEREO-A from Earth, and its separation angle from earth as seen from the sun. The satellite used a 10-watt transmitter operating at a frequency of 2,300 Megahertz .This, by the way, is about 10-times the frequency of a normal UHF TV station.

Date	Distance (Million km)	Intensity ($x10^{-24}$ W/m^2)	Received Power ($x10^{-20}$ Watts)
June-2007	24.6	1316	**126**
August-2007	40.3	490	
October-2007	51.0	306	
December-2007	55.2	261	
February-2008	58.4	234	
April-2008	67.0	177	
June-2008	81.9	119	
August-2008	97.6	84	
October-2008	107.3	69	
December-2008	111.2	64	

Problem 1 - How much weaker was the radio signal from STEREO-A in December 2008 than in June 2007?

Problem 2 - The Deep Space network radio dish has a diameter of 70-meters. In Column 4 calculate how many watts the dish collected from the signals sent during each month.

Problem 3 - If the satellite sends one bit of data ('1' or '0') every 5 seconds, how much energy is detected (in Joules) per bit sent in A)June 2007? and B) December 2008? (1 watt = 1 Joule per second).

Problem 4 - Suppose the receiver cannot detect less radio energy less than 2×10^{-25} Joules each bit. What is the largest number of bits that can be detected each second in A)June 2007 and B)December 2008?

Problem 5 - As a spacecraft gets further and further away from Earth, what kinds of strategies do engineers and scientists have to use to get their data back to Earth?

Answer Key

Problem 1 - How much weaker was the radio signal from STEREO-A in December 2008 than in June 2007? Answer: The signal was 126/6 = 21 times weaker in December than in June.

Problem 2 - Answer:

Date	Distance (Million km)	Intensity ($x10^{-24}$ W/m^2)	Receiver Power ($x10^{-20}$ Watts)
June-2007	24.6	1316	126
August-2007	40.3	490	**47**
October-2007	51.0	306	**29**
December-2007	55.2	261	**25**
February-2008	58.4	234	**22**
April-2008	67.0	177	**17**
June-2008	81.9	119	**11**
August-2008	97.6	84	**8**
October-2008	107.3	69	**7**
December-2008	111.2	64	**6**

Problem 3 - If the satellite sends one bit of data ('1' or '0') every 5 seconds, how much energy is detected (in Joules) per bit sent in A)June 2007? and B)December 2008? (1 watt = 1 Joule per second). Answer: A) 1.26×10^{-18} Joules/sec x 5 sec = 6.3×10^{-18} Joules. B) 6×10^{-20} Joules/sec x 5 sec = 3.0×10^{-19} Joules.

Problem 4 - Suppose the receiver cannot detect less radio energy less than 2×10^{-25} Joules each bit. What is the largest number of bits that can be detected each second in A)June 2007 and B)December 2008? Answer: A) 1.26×10^{-18} Joules/sec / (2.0×10^{-25} Joules/bit) = 6.3 million bits/sec. B) 6×10^{-20} Joules/sec / (2.0×10^{-25} Joules/bit) = 300,000 bits/sec.

Problem 5 - Answer: Here are just a few possibilities: 1) They can use larger radio dishes to increase the signal strength at the receiver. 2) They can slow down the data rates so that the energy per bit is larger making the data more easily detectable. 3) They can design the spacecraft with a more powerful transmitter. 4) They can do all of the above.